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(54) **DETERMINING A PARKING POSITION BASED ON VISUAL AND NON-VISUAL FACTORS**

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(58) **Field of Classification Search**

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(Continued)

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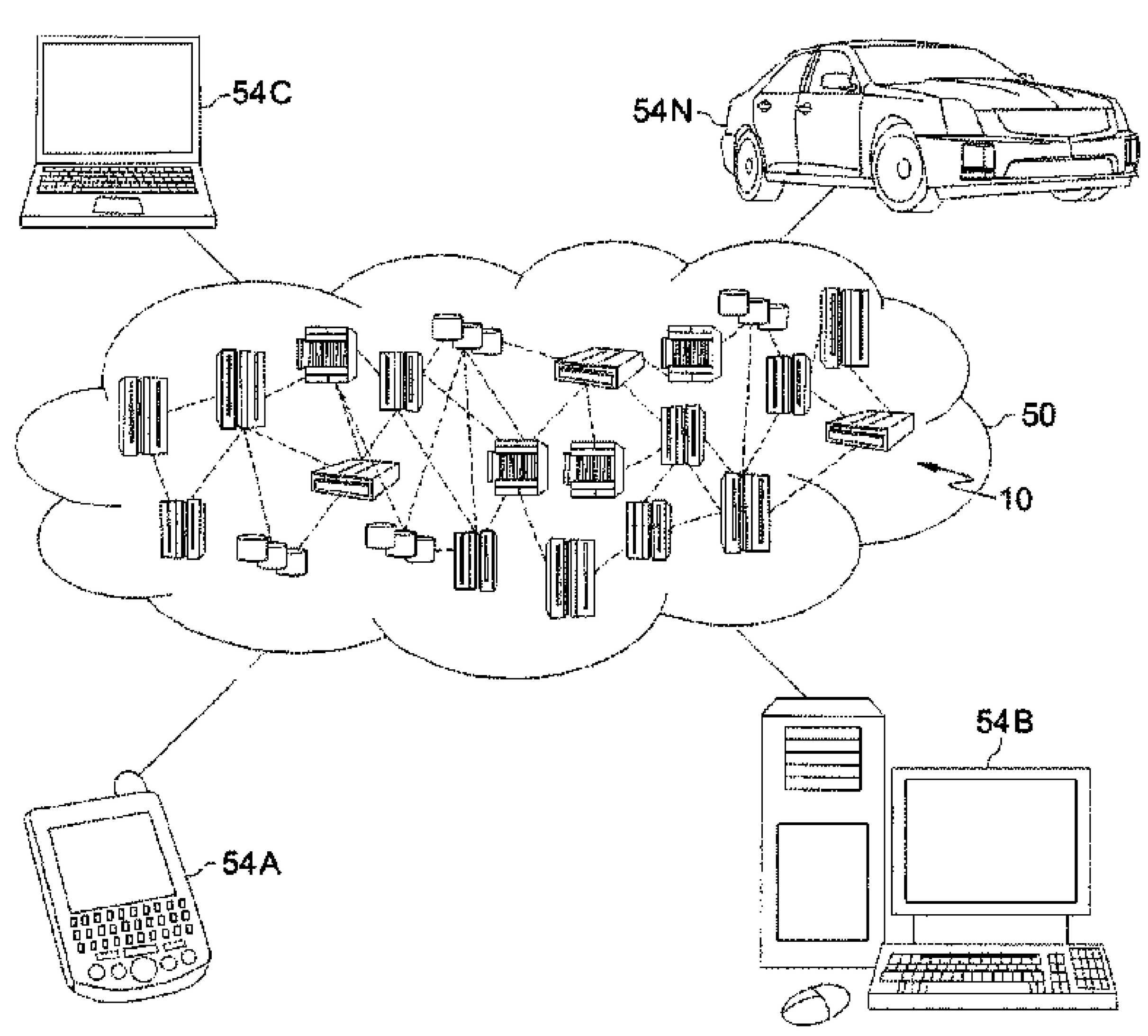
(57) **ABSTRACT**

A computer-implemented method includes: receiving, by a computing device, images of adjacent vehicles parked directly adjacent to an open parking space; determining, by the computing device, visual factors and non-visual factors of the adjacent vehicles based on the images; determining, by the computing device, risk scores for each of the adjacent vehicles based on the visual factor and the non-visual factors; determining, by the computing device, a parking position within the open parking space based on the risk scores; and outputting, by the computing device, information regarding the parking position.

20 Claims, 8 Drawing Sheets



(51) **Int. Cl.**
G06K 9/00 (2006.01)
H04N 7/18 (2006.01)
A01B 69/00 (2006.01)
G01C 22/00 (2006.01)

(58) **Field of Classification Search**
USPC 340/932.2; 348/148; 701/41, 23
See application file for complete search history.

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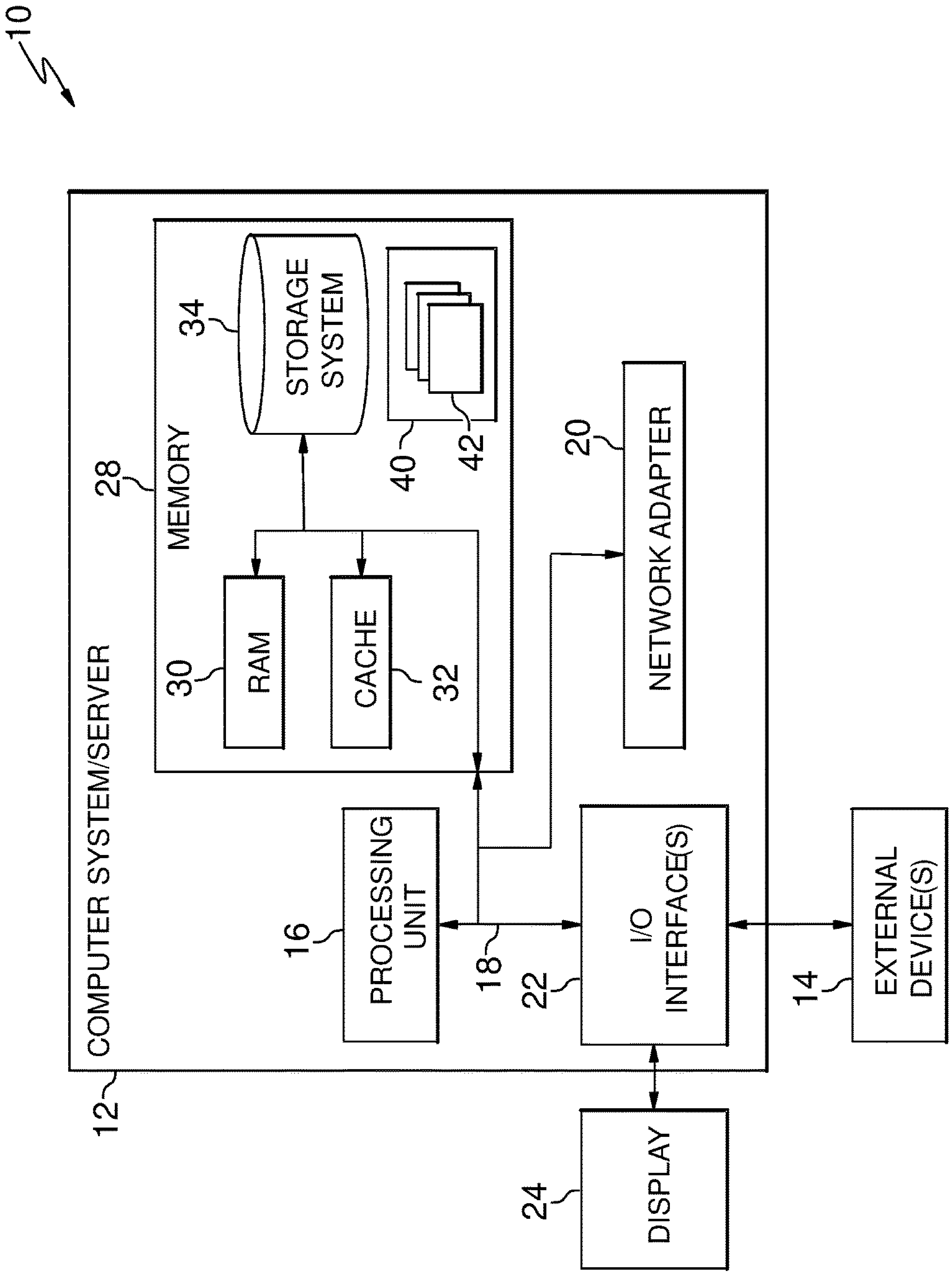

10
12
COMPUTER SYSTEM/SERVER
28
MEMORY
30
RAM
32
CACHE
34
STORAGE SYSTEM
40
42
16
PROCESSING UNIT
18
20
NETWORK ADAPTER
22
I/O INTERFACE(S)
14
EXTERNAL DEVICE(S)
24
DISPLAY

FIG. 1

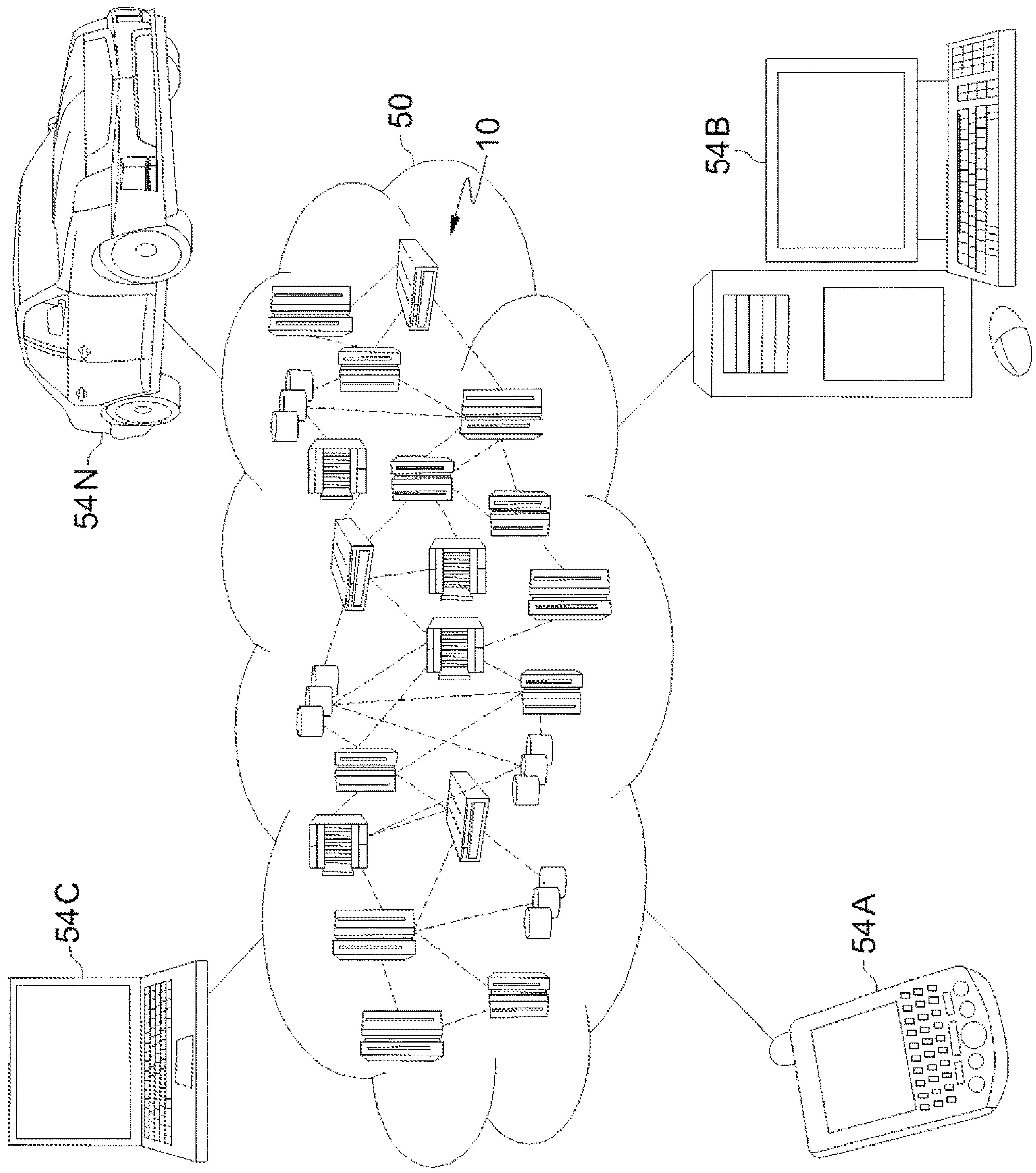
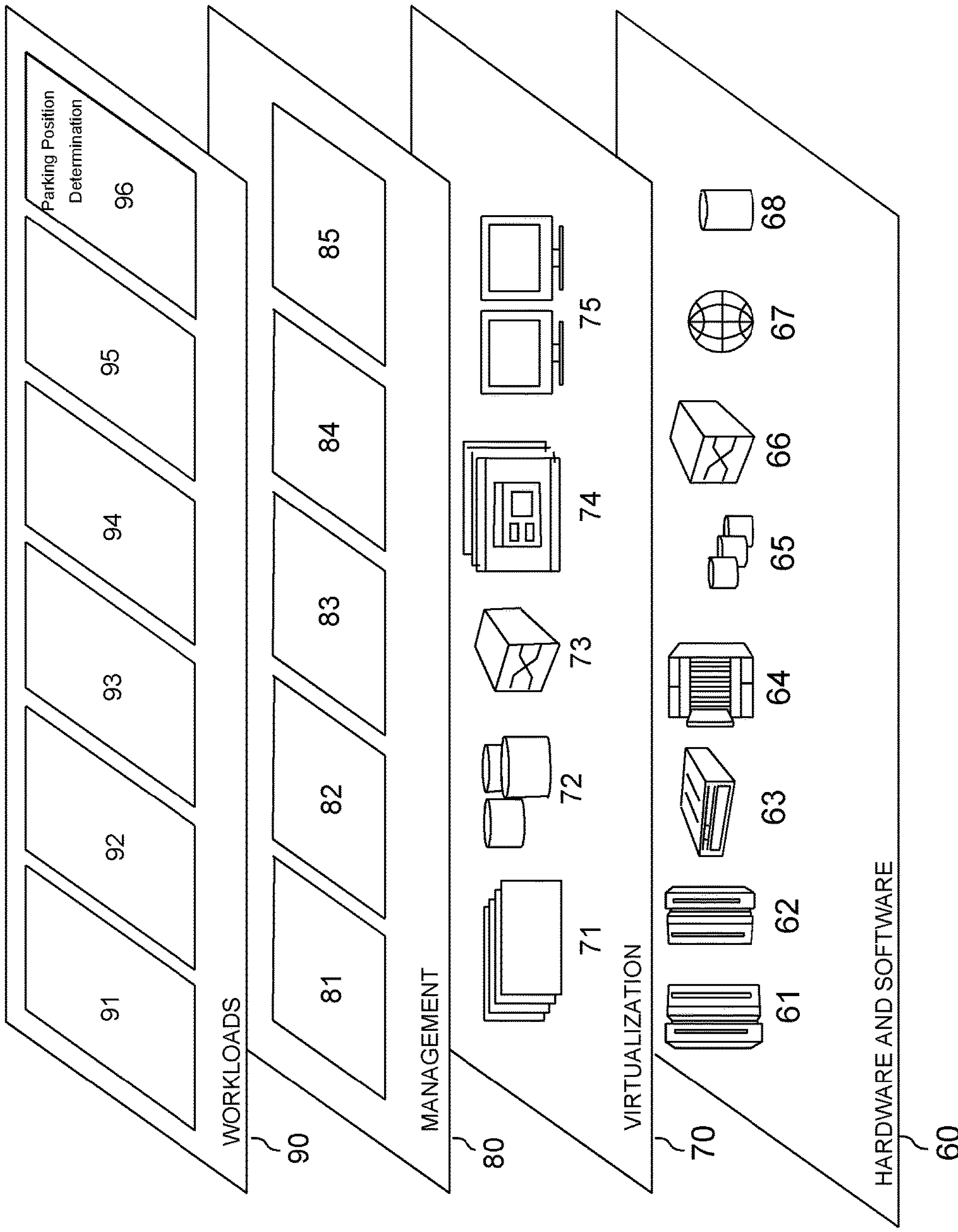
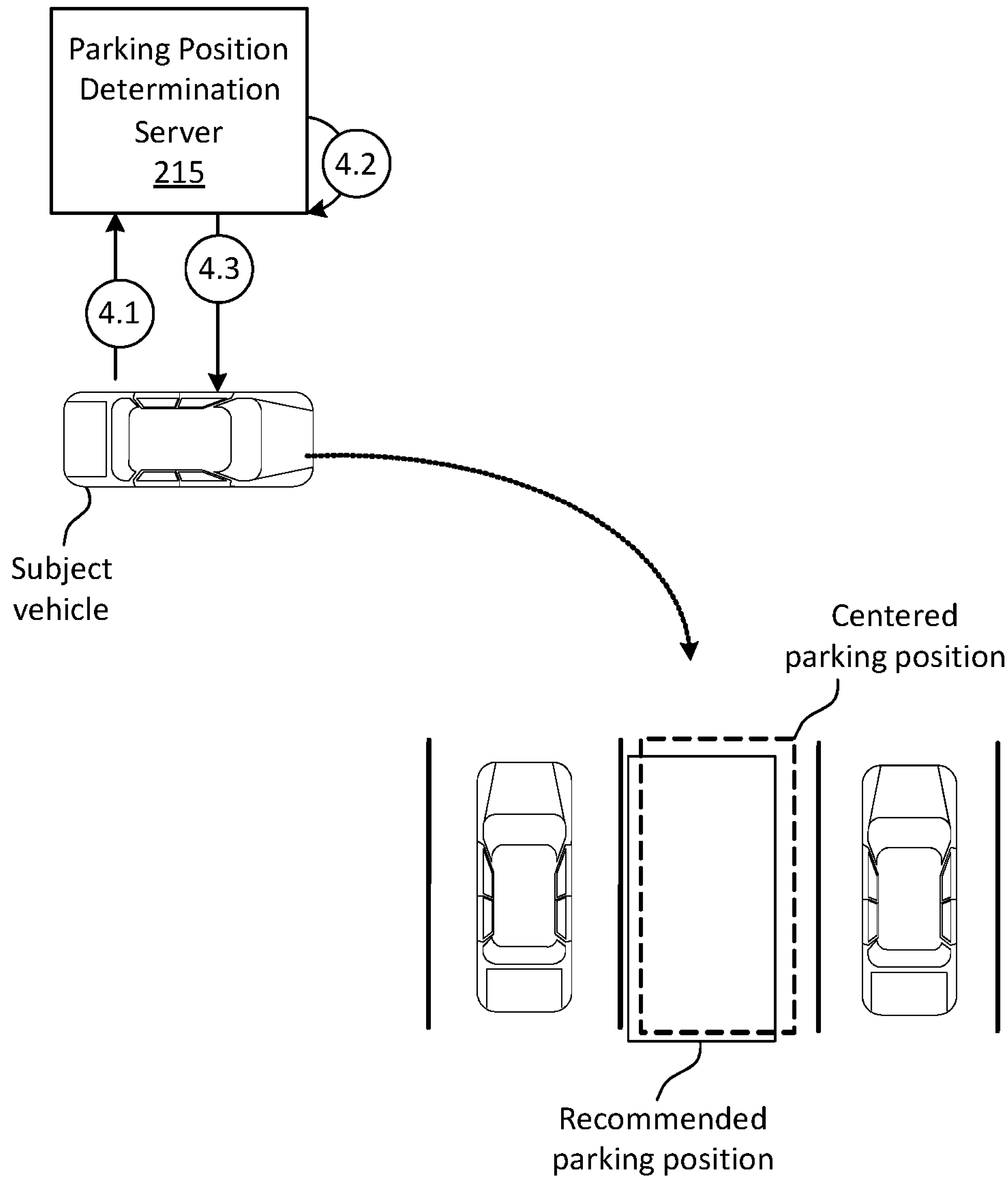


FIG. 2



Parking Position Determination
96
95
94
93
92
91
WORKLOADS
90
85
84
83
82
81
MANAGEMENT
80
75
74
73
72
71
VIRTUALIZATION
70
68
67
66
65
64
63
62
61
HARDWARE AND SOFTWARE
60

FIG. 3



Parking Position Determination Server
215
4.1
4.2
4.3
Subject vehicle
Centered parking position
Recommended parking position

FIG. 4

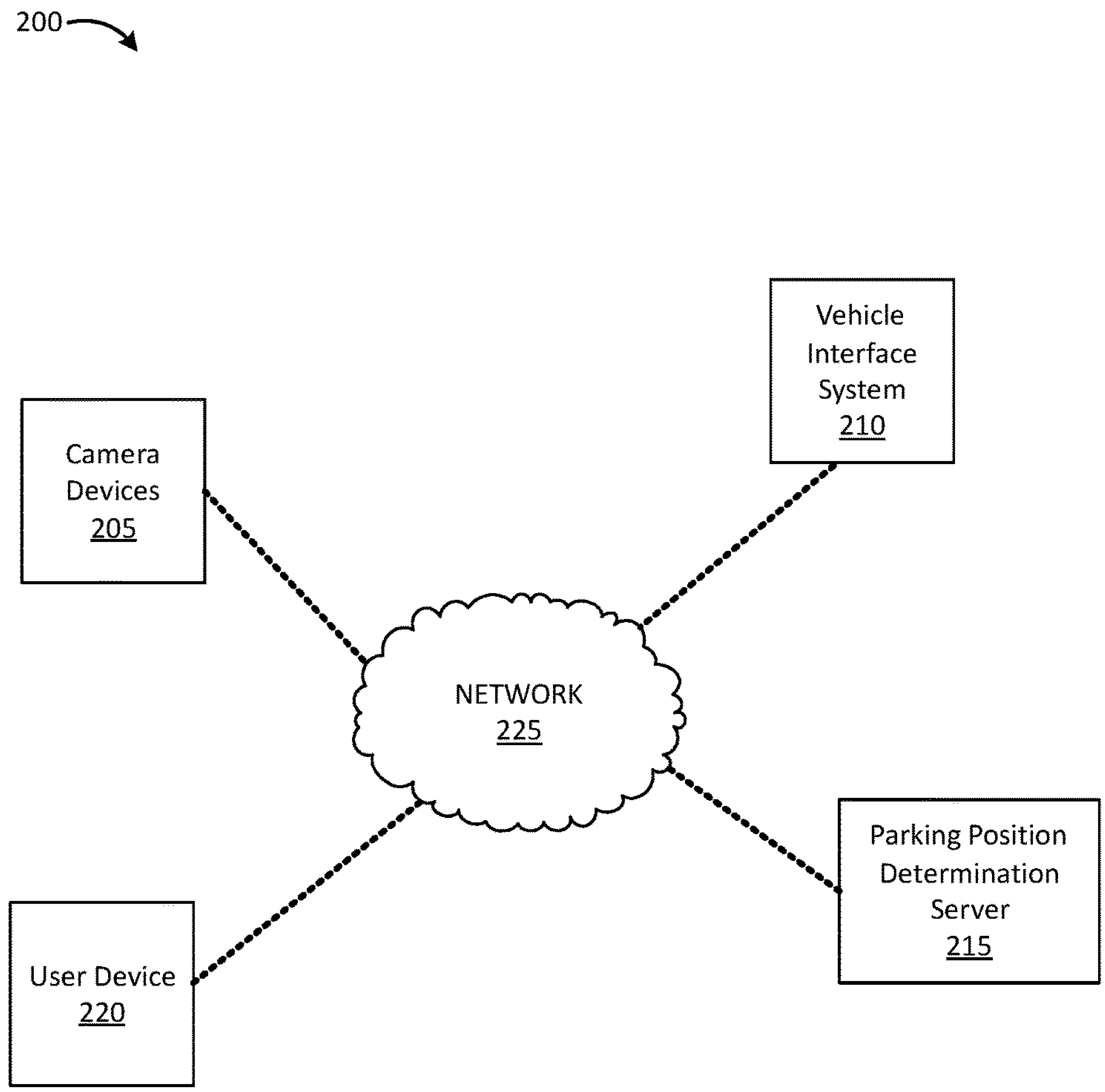

200
Vehicle
Interface
System
210
Camera
Devices
205
NETWORK
225
Parking Position
Determination
Server
215
User Device
220

FIG. 5

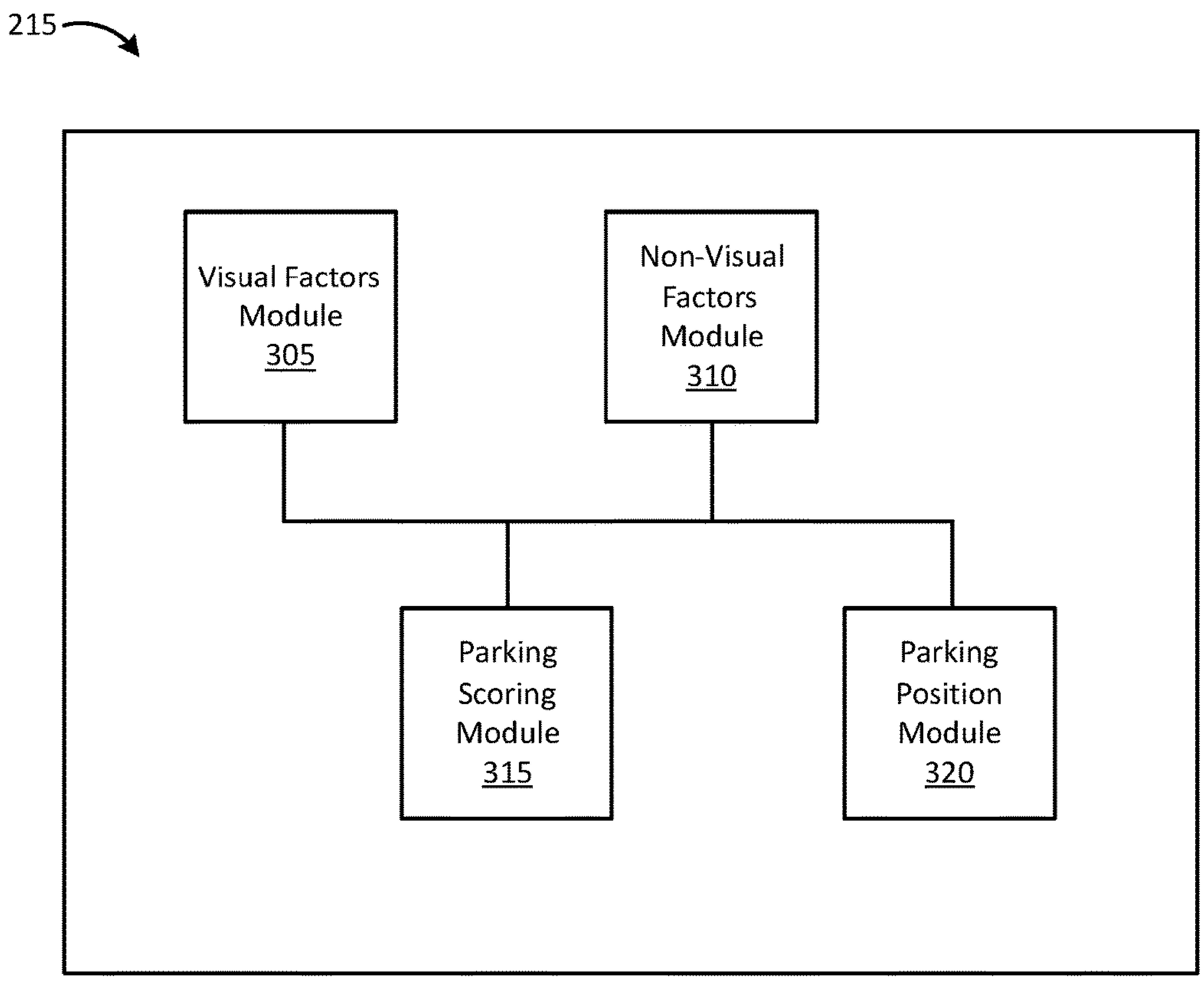

215
Visual Factors Module 305
Non-Visual Factors Module 310
Parking Scoring Module 315
Parking Position Module 320

FIG. 6

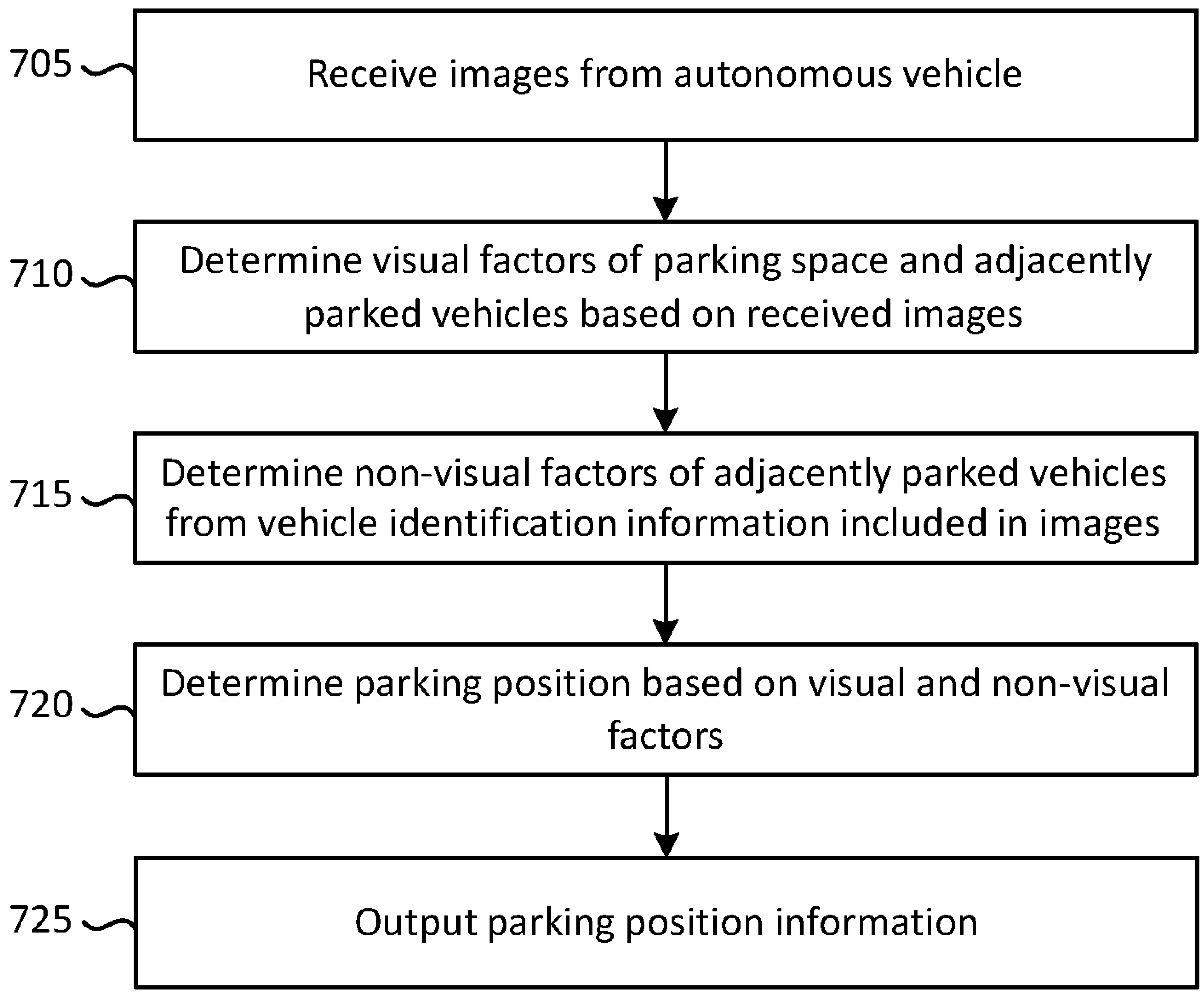

705
Receive images from autonomous vehicle
710
Determine visual factors of parking space and adjacently parked vehicles based on received images
715
Determine non-visual factors of adjacently parked vehicles from vehicle identification information included in images
720
Determine parking position based on visual and non-visual factors
725
Output parking position information

FIG. 7

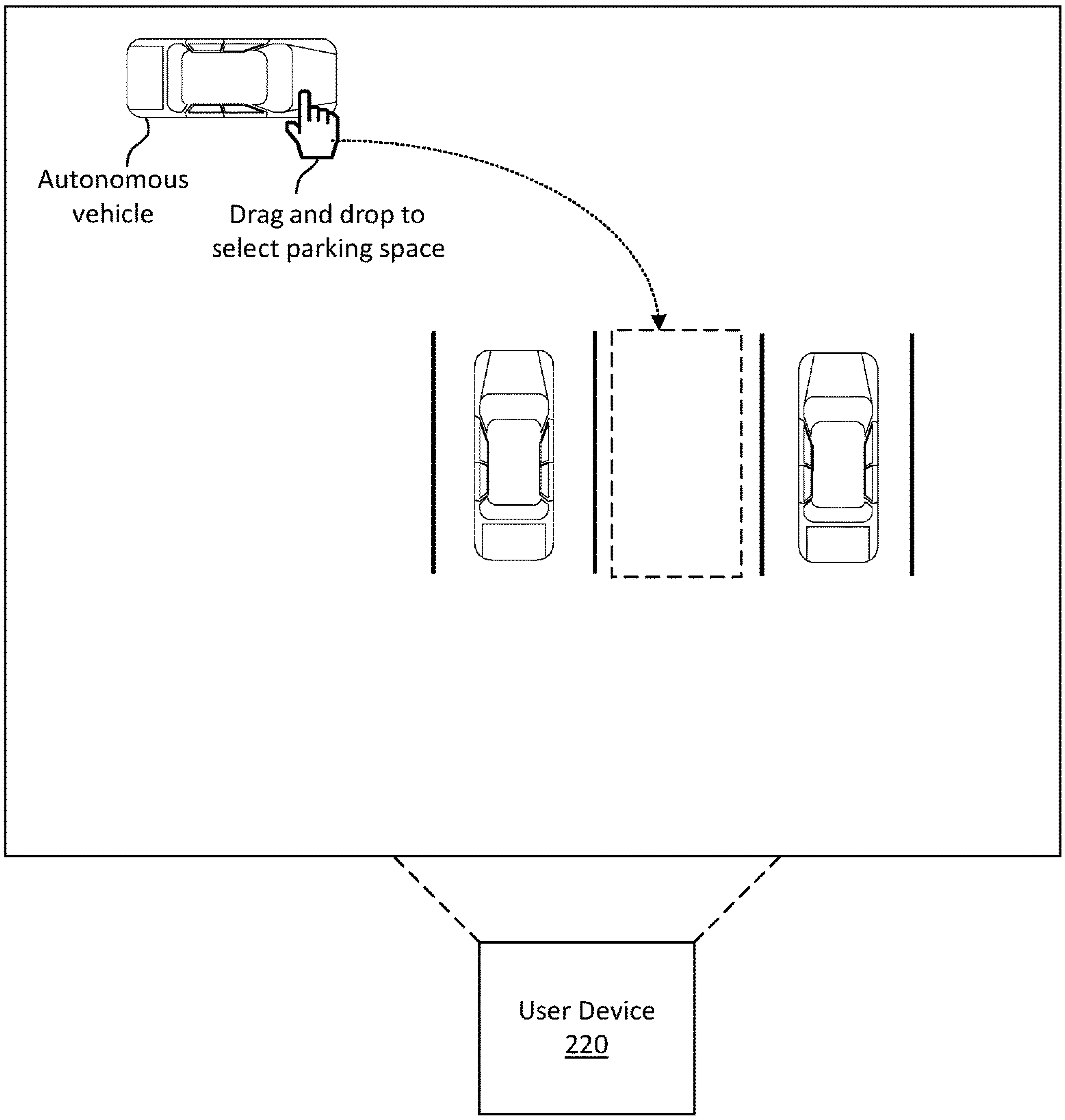

Autonomous vehicle
Drag and drop to select parking space
User Device 220

FIG. 8

DETERMINING A PARKING POSITION BASED ON VISUAL AND NON-VISUAL FACTORS

BACKGROUND

The present invention relates generally to autonomous (self-driving) vehicles, and more particularly, to automatic parking of autonomous vehicles.

Modern vehicle self-parking features use an array of sensors to autonomously park a vehicle in a given spot (such as alongside a curb or in an open parking spot). These systems take a number of factors into consideration such as the size of the parking spot and they work to avoid collisions with other vehicles parked close-by. However factors should be considered when autonomously parking a car in an available parking spot in order to reduce the risk of damage to the vehicle, e.g., by adjacently parked vehicles.

SUMMARY

In an aspect of the invention, a computer-implemented method includes: receiving, by a computing device, images of adjacent vehicles parked directly adjacent to an open parking space; determining, by the computing device, visual factors and non-visual factors of the adjacent vehicles based on the images by obtaining data from a dedicated database; determining, by the computing device, risk scores for each of the adjacent vehicles based on the visual factors and the non-visual factors; determining, by the computing device, a parking position within the open parking space based on the risk scores; and outputting, by the computing device, information regarding the parking position.

In another aspect of the invention, there is a computer program product for determining a parking position for a vehicle. The computer program product includes a computer readable storage medium having program instructions embodied therewith. The program instructions are executable by a computing device to cause the computing device to: receive images of adjacent vehicles parked directly adjacent to an open parking space when a user of an autonomous vehicle instructs the autonomous vehicle to park in the open parking space; determine visual factors and non-visual factors of the adjacent vehicles based on the images; determine risk scores for each of the adjacent vehicles based on the visual factors and the non-visual factors; determine a parking position within the parking space based on the risk scores; and output information regarding the parking position to the user of the autonomous vehicle or to a vehicle interface system of the autonomous vehicle to cause the autonomous vehicle to park in the open space in accordance with the determined parking position.

In another aspect of the invention, a CPU, a computer readable memory and a computer readable storage medium associated with a computing device; program instructions to receive images of adjacent vehicles parked directly adjacent to an open parking space; program instructions to determine visual factors and non-visual factors of the adjacent vehicles based on the images; program instructions to determine risk scores for each of the adjacent vehicles based on the visual factors and the non-visual factors; program instructions to determine a risk score for the open parking space based on the risk scores of each adjacent vehicle; and program instructions to output the risk score for the open parking space. The program instructions are stored on the computer readable storage medium for execution by the CPU via the computer readable memory.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is described in the detailed description which follows, in reference to the noted plurality of drawings by way of non-limiting examples of exemplary embodiments of the present invention.

FIG. **1** depicts a cloud computing node according to an embodiment of the present invention.

FIG. **2** depicts a cloud computing environment according to an embodiment of the present invention.

FIG. **3** depicts abstraction model layers according to an embodiment of the present invention.

FIG. **4** shows an overview of an example implementation in accordance with aspects of the present invention

FIG. **5** shows an example environment in accordance with aspects of the present invention.

FIG. **6** shows a block diagram of example components of a parking selection server in accordance with aspects of the present invention.

FIG. **7** shows an example flowchart for selecting a parking space based on parking space attributes, driver preferences, and vehicle attributes in accordance with aspects of the present invention.

FIG. **8** shows an example user interface in accordance with aspects of the present invention.

DETAILED DESCRIPTION

The present invention relates generally to autonomous (self-driving) vehicles, and more particularly, to automatic parking of autonomous vehicles. In accordance with aspects of the present invention, visual and non-visual factors are used to determine an optimal parking position for a particular autonomous vehicle, e.g., a parking position that reduces the risk of the vehicle being damaged by surrounding vehicles parked adjacent to a vacant parking space. As in illustrative example, assume that vehicles are parked on both left and right sides of a vacant parking space that the particular autonomous vehicle is to park. The visual and non-visual factors may be used to determine risk levels for the vehicles parked adjacent to the vacant parking space. Based on the risk revels, a determination is made that the particular autonomous vehicle should park slightly more towards one of the vehicles, e.g., the vehicle having a lower risk level. As a result, the risk to the now-parked autonomous vehicle is reduced, since the autonomous vehicle is parked farther away from the higher risk vehicle.

In embodiments, visual factors used to determine the risk level for a vehicle may include the vehicle's overall size, door size, door type (sliding or non-sliding), condition, distance to an adjacent parked vehicle, etc. In embodiments, non-visual factors used to determine the risk level for a vehicle may include a vehicle or driver accident history report, driver behavior and experience information, etc.

In aspects of the present invention, an autonomous vehicle may leverage existing camera devices integrated in the autonomous vehicle to provide images to a parking position determination server. Using these images, the parking position determination server may obtain visual factors as well as non-visual factors. For example, the images can be processed using, for example, pixel-based classification techniques and/or other classification techniques to identify visual factors, such as the size of vehicles adjacent to a vacant parking space, visual damage to these vehicles, the size of the vacant space, etc. Further, images of license plates and/or other vehicle identification information can be processed using optical character recognition (OCR) techniques to obtain non-visual factors, such as vehicle or driver accident history report, driver behavior and experience information, etc.

As described herein, both visual and non-visual factors can be used to determine a risk level for each vehicle parked adjacent to a vacant parking space, and these risk levels are used to determine an optimal parking position within the vacant parking space. In an alternative embodiment, a risk score can be generated for the vacant parking space, and based on the risk score, a decision can be made as to whether the autonomous vehicle should accept the space, e.g., park in the space, or if it should decline to park in the space and search for a different space.

The present invention may be a system, a method, and/or a computer program product. The computer program product may include a computer readable storage medium (or media) having computer readable program instructions thereon for causing a processor to carry out aspects of the present invention.

The computer readable storage medium can be a tangible device that can retain and store instructions for use by an instruction execution device. The computer readable storage medium may be, for example, but is not limited to, an electronic storage device, a magnetic storage device, an optical storage device, an electromagnetic storage device, a semiconductor storage device, or any suitable combination of the foregoing. A non-exhaustive list of more specific examples of the computer readable storage medium includes the following: a portable computer diskette, a hard disk, a random access memory (RAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a static random access memory (SRAM), a portable compact disc read-only memory (CD-ROM), a digital versatile disk (DVD), a memory stick, a floppy disk, a mechanically encoded device such as punch-cards or raised structures in a groove having instructions recorded thereon, and any suitable combination of the foregoing. A computer readable storage medium, as used herein, is not to be construed as being transitory signals per se, such as radio waves or other freely propagating electromagnetic waves, electromagnetic waves propagating through a waveguide or other transmission media (e.g., light pulses passing through a fiber-optic cable), or electrical signals transmitted through a wire.

Computer readable program instructions described herein can be downloaded to respective computing/processing devices from a computer readable storage medium or to an external computer or external storage device via a network, for example, the Internet, a local area network, a wide area network and/or a wireless network. The network may comprise copper transmission cables, optical transmission fibers, wireless transmission, routers, firewalls, switches, gateway computers and/or edge servers. A network adapter card or network interface in each computing/processing device receives computer readable program instructions from the network and forwards the computer readable program instructions for storage in a computer readable storage medium within the respective computing/processing device.

Computer readable program instructions for carrying out operations of the present invention may be assembler instructions, instruction-set-architecture (ISA) instructions, machine instructions, machine dependent instructions, microcode, firmware instructions, state-setting data, or either source code or object code written in any combination of one or more programming languages, including an object oriented programming language such as Smalltalk, C++ or the like, and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The computer readable program instructions may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider). In some embodiments, electronic circuitry including, for example, programmable logic circuitry, field-programmable gate arrays (FPGA), or programmable logic arrays (PLA) may execute the computer readable program instructions by utilizing state information of the computer readable program instructions to personalize the electronic circuitry, in order to perform aspects of the present invention.

Aspects of the present invention are described herein with reference to flowchart illustrations and/or block diagrams of methods, apparatus (systems), and computer program products according to embodiments of the invention. It will be understood that each block of the flowchart illustrations and/or block diagrams, and combinations of blocks in the flowchart illustrations and/or block diagrams, can be implemented by computer readable program instructions.

These computer readable program instructions may be provided to a processor of a general purpose computer, special purpose computer, or other programmable data processing apparatus to produce a machine, such that the instructions, which execute via the processor of the computer or other programmable data processing apparatus, create means for implementing the functions/acts specified in the flowchart and/or block diagram block or blocks. These computer readable program instructions may also be stored in a computer readable storage medium that can direct a computer, a programmable data processing apparatus, and/or other devices to function in a particular manner, such that the computer readable storage medium having instructions stored therein comprises an article of manufacture including instructions which implement aspects of the function/act specified in the flowchart and/or block diagram block or blocks.

The computer readable program instructions may also be loaded onto a computer, other programmable data processing apparatus, or other device to cause a series of operational steps to be performed on the computer, other programmable apparatus or other device to produce a computer implemented process, such that the instructions which execute on the computer, other programmable apparatus, or other device implement the functions/acts specified in the flowchart and/or block diagram block or blocks.

The flowcharts and block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments of the present invention. In this regard, each block in the flowcharts may represent a module, segment, or portion of instructions, which comprises one or more executable instructions for implementing the specified logical function (s). In some alternative implementations, the functions noted in the block may occur out of the order noted in the figures.

For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved. It will also be noted that each block of the flowchart illustrations, and combinations of blocks in the flowchart illustrations, can be implemented by special purpose hardware-based systems that perform the specified functions or acts or carry out combinations of special purpose hardware and computer instructions.

It is understood in advance that although this disclosure includes a detailed description on cloud computing, implementation of the teachings recited herein are not limited to a cloud computing environment. Rather, embodiments of the present invention are capable of being implemented in conjunction with any other type of computing environment now known or later developed.

Cloud computing is a model of service delivery for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, network bandwidth, servers, processing, memory, storage, applications, virtual machines, and services) that can be rapidly provisioned and released with minimal management effort or interaction with a provider of the service. This cloud model may include at least five characteristics, at least three service models, and at least four deployment models.

Characteristics are as follows:

On-demand self-service: a cloud consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with the service's provider.

Broad network access: capabilities are available over a network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and PDAs).

Resource pooling: the provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to demand. There is a sense of location independence in that the consumer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter).

Rapid elasticity: capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out and rapidly released to quickly scale in. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.

Measured service: cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported providing transparency for both the provider and consumer of the utilized service.

Service Models are as follows:

Software as a Service (SaaS): the capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based e-mail). The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.

Platform as a Service (PaaS): the capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including networks, servers, operating systems, or storage, but has control over the deployed applications and possibly application hosting environment configurations.

Infrastructure as a Service (IaaS): the capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of select networking components (e.g., host firewalls).

Deployment Models are as follows:

Private cloud: the cloud infrastructure is operated solely for an organization. It may be managed by the organization or a third party and may exist on-premises or off-premises.

Community cloud: the cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be managed by the organizations or a third party and may exist on-premises or off-premises.

Public cloud: the cloud infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services.

Hybrid cloud: the cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load-balancing between clouds).

A cloud computing environment is service oriented with a focus on statelessness, low coupling, modularity, and semantic interoperability. At the heart of cloud computing is an infrastructure comprising a network of interconnected nodes.

Referring now to FIG. **1**, a schematic of an example of a cloud computing node is shown. Cloud computing node **10** is only one example of a suitable cloud computing node and is not intended to suggest any limitation as to the scope of use or functionality of embodiments of the invention described herein. Regardless, cloud computing node **10** is capable of being implemented and/or performing any of the functionality set forth hereinabove.

In cloud computing node **10** there is a computer system/server **12**, which is operational with numerous other general purpose or special purpose computing system environments or configurations. Examples of well-known computing systems, environments, and/or configurations that may be suitable for use with computer system/server **12** include, but are not limited to, personal computer systems, server computer systems, thin clients, thick clients, hand-held or laptop devices, multiprocessor systems, microprocessor-based systems, set top boxes, programmable consumer electronics, network PCs, minicomputer systems, mainframe computer systems, and distributed cloud computing environments that include any of the above systems or devices, and the like.

Computer system/server **12** may be described in the general context of computer system executable instructions, such as program modules, being executed by a computer system. Generally, program modules may include routines, programs, objects, components, logic, data structures, and so on that perform particular tasks or implement particular abstract data types. Computer system/server **12** may be practiced in distributed cloud computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed cloud computing environment, program modules may be located in both local and remote computer system storage media including memory storage devices.

As shown in FIG. **1**, computer system/server **12** in cloud computing node **10** is shown in the form of a general-purpose computing device. The components of computer system/server **12** may include, but are not limited to, one or more processors or processing units **16**, a system memory **28**, and a bus **18** that couples various system components including system memory **28** to processor **16**.

Bus **18** represents one or more of any of several types of bus structures, including a memory bus or memory controller, a peripheral bus, an accelerated graphics port, and a processor or local bus using any of a variety of bus architectures. By way of example, and not limitation, such architectures include Industry Standard Architecture (ISA) bus, Micro Channel Architecture (MCA) bus, Enhanced ISA (EISA) bus, Video Electronics Standards Association (VESA) local bus, and Peripheral Component Interconnects (PCI) bus.

Computer system/server **12** typically includes a variety of computer system readable media. Such media may be any available media that is accessible by computer system/server **12**, and it includes both volatile and non-volatile media, removable and non-removable media.

System memory **28** can include computer system readable media in the form of volatile memory, such as random access memory (RAM) **30** and/or cache memory **32**. Computer system/server **12** may further include other removable/non-removable, volatile/non-volatile computer system storage media. By way of example only, storage system **34** can be provided for reading from and writing to a nonremovable, non-volatile magnetic media (not shown and typically called a "hard drive"). Although not shown, a magnetic disk drive for reading from and writing to a removable, non-volatile magnetic disk (e.g., a "floppy disk"), and an optical disk drive for reading from or writing to a removable, non-volatile optical disk such as a CD-ROM, DVD-ROM or other optical media can be provided. In such instances, each can be connected to bus **18** by one or more data media interfaces. As will be further depicted and described below, memory **28** may include at least one program product having a set (e.g., at least one) of program modules that are configured to carry out the functions of embodiments of the invention.

Program/utility **40**, having a set (at least one) of program modules **42**, may be stored in memory **28** by way of example, and not limitation, as well as an operating system, one or more application programs, other program modules, and program data. Each of the operating system, one or more application programs, other program modules, and program data or some combination thereof, may include an implementation of a networking environment. Program modules **42** generally carry out the functions and/or methodologies of embodiments of the invention as described herein.

Computer system/server **12** may also communicate with one or more external devices **14** such as a keyboard, a pointing device, a display **24**, etc.; one or more devices that enable a user to interact with computer system/server **12**; and/or any devices (e.g., network card, modem, etc.) that enable computer system/server **12** to communicate with one or more other computing devices. Such communication can occur via Input/Output (I/O) interfaces **22**. Still yet, computer system/server **12** can communicate with one or more networks such as a local area network (LAN), a general wide area network (WAN), and/or a public network (e.g., the Internet) via network adapter **20**. As depicted, network adapter **20** communicates with the other components of computer system/server **12** via bus **18**. It should be understood that although not shown, other hardware and/or software components could be used in conjunction with computer system/server **12**. Examples, include, but are not limited to: microcode, device drivers, redundant processing units, external disk drive arrays, RAID systems, tape drives, and data archival storage systems, etc.

Referring now to FIG. **2**, illustrative cloud computing environment **50** is depicted. As shown, cloud computing environment **50** comprises one or more cloud computing nodes **10** with which local computing devices used by cloud consumers, such as, for example, personal digital assistant (PDA) or cellular telephone **54**A, desktop computer **54**B, laptop computer **54**C, and/or automobile computer system **54**N may communicate. Nodes **10** may communicate with one another. They may be grouped (not shown) physically or virtually, in one or more networks, such as Private, Community, Public, or Hybrid clouds as described hereinabove, or a combination thereof. This allows cloud computing environment **50** to offer infrastructure, platforms and/or software as services for which a cloud consumer does not need to maintain resources on a local computing device. It is understood that the types of computing devices **54**A-N shown in FIG. **2** are intended to be illustrative only and that computing nodes **10** and cloud computing environment **50** can communicate with any type of computerized device over any type of network and/or network addressable connection (e.g., using a web browser).

Referring now to FIG. **3**, a set of functional abstraction layers provided by cloud computing environment **50** (FIG. **2**) is shown. It should be understood in advance that the components, layers, and functions shown in FIG. **3** are intended to be illustrative only and embodiments of the invention are not limited thereto. As depicted, the following layers and corresponding functions are provided:

Hardware and software layer **60** includes hardware and software components. Examples of hardware components include: mainframes **61**; RISC (Reduced Instruction Set Computer) architecture based servers **62**; servers **63**; blade servers **64**; storage devices **65**; and networks and networking components **66**. In some embodiments, software components include network application server software **67** and database software **68**.

Virtualization layer **70** provides an abstraction layer from which the following examples of virtual entities may be provided: virtual servers **71**; virtual storage **72**; virtual networks **73**, including virtual private networks; virtual applications and operating systems **74**; and virtual clients **75**.

In one example, management layer **80** may provide the functions described below. Resource provisioning **81** provides dynamic procurement of computing resources and other resources that are utilized to perform tasks within the cloud computing environment. Metering and Pricing **82** provide cost tracking as resources are utilized within the cloud computing environment, and billing or invoicing for consumption of these resources. In one example, these resources may comprise application software licenses. Security provides identity verification for cloud consumers and tasks, as well as protection for data and other resources. User portal **83** provides access to the cloud computing environment for consumers and system administrators. Service level management **84** provides cloud computing resource allocation and management such that required service levels are met. Service Level Agreement (SLA) planning and fulfillment **85** provide pre-arrangement for, and procurement of, cloud computing resources for which a future requirement is anticipated in accordance with an SLA.

Workloads layer **90** provides examples of functionality for which the cloud computing environment may be utilized. Examples of workloads and functions which may be provided from this layer include: mapping and navigation **91**; software development and lifecycle management **92**; virtual classroom education delivery **93**; data analytics processing **94**; transaction processing **95**; and parking position determination **96**.

Referring back to FIG. **1**, the program/utility **40** may include one or more program modules **42** that generally carry out the functions and/or methodologies of embodiments of the invention as described herein. Specifically, the program modules **42** may receive images from an autonomous vehicle, determine visual and non-visual factors based on the images, determine a parking position for the autonomous vehicle based on the visual and non-visual factors, and output information regarding the parking position to the autonomous vehicle. Other functionalities of the program modules **42** are described further herein such that the program modules **42** are not limited to the functions described above. Moreover, it is noted that some of the modules **42** can be implemented within the infrastructure shown in FIGS. **1-3**. For example, the modules **42** may be representative of a parking selection server as shown in FIG. **4**.

FIG. **4** shows an overview of an example implementation in accordance with aspects of the present invention. As shown in FIG. **4**, a subject vehicle, e.g., an autonomous vehicle, may identify an open parking space in a parking facility. At step **4.1**, the subject vehicle may provide, to a parking position determination server **215**, images of the parking space and of the vehicles parked adjacent to the parking space. In embodiments, the subject vehicle may drive forward and then backward in order to capture a sufficient number of images of the parking space and the adjacent vehicles at various angles. Based on receiving these images (at step **4.2**), the parking position determination server **215** may determine visual and non-visual factors for vehicles parked adjacent to the open parking space. The visual and non-visual factors may be used to determine an optimal parking position for the subject vehicle, e.g., a position that improves safety and reduces the risk of the vehicle being damaged by an adjacently parked vehicle. For example, as described herein, visual factors may include the vehicle's overall size, door size, door type (sliding or non-sliding), condition, distance to an adjacent parked vehicle etc. Non-visual factors may be obtained, for example, by analyzing vehicle identification information, e.g., a license plate number. From the vehicle identification information, non-visual factors may be determined, such as a vehicle or driver accident history report, driver behavior and experience information, etc.

It is noted that certain factors may be considered visual or non-visual. For example, published vehicle data, such as door sizes and door types, etc. can be considered either visual or non-visual since these factors may or may not be able to be visually identified from the images. However, published vehicle data can be obtained from the vehicle identification information, such as vehicle dimensions, door types, etc. This vehicle data, along with other visual and non-visual factors, can be used to determine risk levels for vehicles adjacent to a vacant parking space.

Based on determining the risk levels, a recommended parking position is determined by the parking position determination server **215**, and information identifying the recommended parking position is provided to the subject vehicle (at step **4.3**). For example, the recommended parking position may identify that the subject vehicle should park off-center, and slightly closer to the lower risk vehicle. The subject vehicle may then self-park in accordance with the recommended parking position. In the example shown in FIG. **4**, the subject vehicle may park slightly off center and towards the adjacent vehicle on the left hand side, e.g., assuming that the adjacent vehicle on the left hand side is considered lower risk than the adjacent vehicle on the right hand side.

FIG. **5** shows an example environment in accordance with aspects of the present invention. As shown in FIG. **5**, environment **200** may include camera devices **205**, a vehicle interface system **210**, a parking position determination server **215**, a user device **220**, and/or a network **225**. In embodiments, one or more components in environment **200** may correspond to one or more components in the cloud computing environment of FIG. **2**.

The camera devices **205** may be integrated into an autonomous vehicle. The camera devices **205** may capture images of an open parking space and of vehicles parked adjacent to the open parking space. Additionally, or alternatively, the camera devices **205** may be provided at a parking facility. The camera devices **205** provide images of an open parking space and of vehicles parked adjacent to the open parking space to the parking position determination server **215**.

The vehicle interface system **210** may be integrated into an autonomous vehicle and receives parking position information from the parking position determination server **215**. Based on receiving this information, the vehicle interface system **210** causes the autonomous vehicle to park in an open space in accordance with the parking position information. In alternative embodiments, the vehicle interface system **210** may receive a risk score for an open parking space. If the risk score is below a particular threshold, the vehicle interface system **210** causes the autonomous vehicle to park in an open space in accordance with the parking position information. If the risk score is above a particular threshold, the vehicle interface system **210** can cause the vehicle to continue to search for additional open spaces in the parking facility.

The parking position determination server **215** may include one or more computing devices, such as a cloud server, that receive images from the camera devices **205** of an autonomous vehicle. In accordance with aspects of the present invention, the parking position determination server **215** receives the images when the autonomous vehicle has identified an open parking space. Based on receiving the images, the parking position determination server **215** identifies visual and non-visual factors, and determines a parking position based on these factors.

The user device **220** may include any device capable of communicating via a network, such as the network **225**. For example, the user device **220** may correspond to a mobile communication device (e.g., a smart phone or a personal digital assistant (PDA)), a portable computer device (e.g., a laptop or a tablet computer), or another type of device. In some embodiments, the user device **220** may be used to control an autonomous vehicle. For example, the user device **220** may implement an application that allows a user to select an open parking space for the autonomous vehicle to park. In embodiments, the user device **220** may receive real-video feeds from a camera device **205** associated with a parking facility, and the real-time video can be used to allow the user to select an open parking space for the autonomous vehicle to park.

The network **225** may include network nodes, such as network nodes **10** of FIG. **2**. Additionally, or alternatively, the network **225** may include one or more wired and/or wireless networks. For example, the network **225** may include a cellular network (e.g., a second generation (2G) network, a third generation (3G) network, a fourth generation (4G) network, a fifth generation (5G) network, a long-term evolution (LTE) network, a global system for mobile (GSM) network, a code division multiple access (CDMA) network, an evolution-data optimized (EVDO) network, or the like), a public land mobile network (PLMN), and/or another network. Additionally, or alternatively, the network **225** may include a local area network (LAN), a wide area network (WAN), a metropolitan network (MAN), the Public Switched Telephone Network (PSTN), an ad hoc network, a managed Internet Protocol (IP) network, a virtual private network (VPN), an intranet, the Internet, a fiber optic-based network, and/or a combination of these or other types of networks.

The quantity of devices and/or networks in the environment **200** is not limited to what is shown in FIG. **5**. In practice, the environment **200** may include additional devices and/or networks; fewer devices and/or networks; different devices and/or networks; or differently arranged devices and/or networks than illustrated in FIG. **5**. Also, in some implementations, one or more of the devices of the environment **200** may perform one or more functions described as being performed by another one or more of the devices of the environment **200**. Devices of the environment **200** may interconnect via wired connections, wireless connections, or a combination of wired and wireless connections.

FIG. **6** shows a block diagram of example components of a parking position determination server **215** in accordance with aspects of the present invention. As shown in FIG. **6**, the parking position determination server **215** may include a visual factors module **305**, a non-visual factors module **310**, a parking scoring module **315**, and a parking position module **320**. In embodiments, the parking position determination server **215** may include additional or fewer components than those shown in FIG. **6**. In embodiments, separate components may be integrated into a single computing component or module. Additionally, or alternatively, a single component may be implemented as multiple computing components or modules.

The visual factors module **305** may comprise a program module (e.g., program module **42** of FIG. **1**) that receives, from the camera devices **205** of an autonomous vehicle and/or a parking facility, images of an open parking space and of vehicles parked adjacent to the open parking space. Based on these images, the visual factors module **305** may identify visual factors that indicate the risk level of the parked vehicles and/or an overall risk level of the open parking space. For example, the visual factors module **305** may use pixel-based classification and/or other image processing techniques to identify visual factors, such as an adjacent vehicle's overall size, door size, door type (sliding or non-sliding), condition/damage, distance to another adjacently parked vehicle, etc. In embodiments, the visual factors module **305** may identify information indicating driver experience. For example, the visual factors module **305** may identify a bumper/window sticker or other indicia that indicates is a novice driver, e.g., indicia that reads "Student Driver" or the like.

The non-visual factors module **310** may comprise a program module (e.g., program module **42** of FIG. **1**) that receives, from the camera devices **205** of an autonomous vehicle and/or parking facility, images of an open parking space and of vehicles parked adjacent to the open parking space. Based on these images, the non-visual factors module **310** may identify non-visual factors that indicate the risk level of the parked vehicles and/or an overall risk level of the open parking space. For example, the non-visual factors module **310** may use optical character recognition (OCR) techniques and/or other techniques to identify vehicle identification information for the parked vehicles, such as license plates and/or other vehicle identification information. Based on the vehicle identification information, the non-visual factors module **310** may obtain non-visual factors, such as vehicle or driver accident history report, driver behavior and experience information, etc. For example, the non-visual factors module **310** may access and search a dedicated database, such as a vehicle accident database that includes driver accident history information, and/or vehicle accident history information based on the vehicle identification information, Further, the non-visual factors module **310** may access and search a vehicle registration database that includes driver experience information based on the vehicle identification information. Also based on the vehicle identification information, the non-visual factors module **310** may obtain certain factors that may be considered either visual or non-visual, such as door sizes and door types, since these factors may or may not visually apparent from the images. For example, the non-visual factors module **310** may obtain these non-visual factors by accessing and searching a vehicle information database.

The parking scoring module **315** may comprise a program module (e.g., program module **42** of FIG. **1**) that generates a score for each vehicle parked directly adjacent to an open parking space based on the visual and non-visual factors. The score identifies a measure of risk associated with each adjacent vehicle. As an illustrative example, the score would indicate a relatively riskier adjacent vehicle if the adjacent vehicle has visual damage, is parked relatively close to the open parking space, has relatively large doors, and/or whose driver has a relatively poor driving record (e.g., a relatively higher number of accidents, relatively low amount of driving experience, etc.) In alternative embodiments, the parking scoring module **315** may generate a score for the open parking space. The score for the open parking space may be based on the score of the vehicles parked directly adjacent to the open parking space. In embodiments, the score for the open parking space can be provided to a user device **220** and/or a vehicle interface system **210** associated with an autonomous vehicle. If the score does not satisfy a particular threshold, a user of the autonomous vehicle (or the autonomous vehicle itself) may decline to park in the parking space. In embodiments, each visual and/or non-visual factor may be weighted, and the score may be based on these weightings. For example, visual damage can be weighted differently than door clearance, and driver accident history can be weighted differently than the size of the open parking space.

The parking position module **320** may comprise a program module (e.g., program module **42** of FIG. **1**) that determines an optimum parking position within the open parking space based on the risk scores of the vehicles parked directly adjacent to the open space. For example, the parking position module **320** may determine that the autonomous vehicle should park off-center and closer to the adjacent vehicle that has the lower risk score. The parking position module **320** may provide information identifying the parking position to the vehicle interface system **210** of the autonomous vehicle. Based on receiving the parking position information, the vehicle interface system **210** may direct the autonomous vehicle to park in the parking space in accordance with the determined parking position.

FIG. **7** shows an example flowchart for determining and outputting parking position information. The steps of FIG. **7** may be implemented in the environment of FIG. **1**, for example. As noted above, the flowchart illustrates the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments of the present invention.

At step **705**, images from an autonomous vehicle are received. For example, the parking position determination server **215** receives the images when the autonomous vehicle has identified an open parking space. In embodiments, the autonomous vehicle can identify an open parking space based on object sensing and/or pixel-based classification techniques. In embodiments, the autonomous vehicle may identify the open parking space when automatically driving and searching for an open parking in a parking facility. Additionally, or alternatively, the autonomous vehicle may identify the open parking space when a user of the autonomous vehicle has remotely instructed the autonomous vehicle, e.g., using a user device **220**, to park in an open parking space.

In an alternative embodiment, the images can be received from another source other than an autonomous vehicle. For example, the images can be received from camera devices **205** implemented in a parking facility.

At step **710**, visual factors of the parking space and of vehicles parked directly adjacent to the parking space are determined based on the received images. For example, the parking position determination server **215** may identify visual factors that indicate the risk level of the parked vehicles and/or an overall risk level of the open parking space. For example, the visual factors module **305** may identify visual factors, such as an adjacent vehicle's overall size, door size, door type (sliding or non-sliding), condition/damage, distance to another adjacently parked vehicle, etc.

At step **715**, non-visual factors of the adjacently parked vehicles are determined from vehicle identification information included in the images. For example, the parking position determination server **215** may use OCR techniques and/or other techniques to identify vehicle identification information for the parked vehicles, such as license plates and/or other vehicle identification information. Based on the vehicle identification information, the non-visual factors module **310** may obtain non-visual factors, such as vehicle or driver accident history report, driver behavior and experience information, etc. Also based on the vehicle identification information, the non-visual factors module **310** may obtain certain factors that may be considered either visual or non-visual, such as door sizes and door types, since these factors may or may not visually apparent from the images.

At step **720**, a parking position is determined based on the visual and non-visual factors. For example, the parking position determination server **215** may determine the parking position by scoring the adjacently parked vehicles in terms of risk levels. As an illustrative example, the score would indicate a relatively riskier adjacent vehicle if the adjacent vehicle has visual damage, is parked relatively close to the open parking space, has relatively large doors, and/or whose driver has a relatively poor driving record (e.g., a relatively higher number of accidents, relatively low amount of driving experience, etc.). The parking position determination server **215** may determine a parking position that the autonomous vehicle should park in the open parking space based on the risk scores of the vehicles parked directly adjacent to the open space. For example, the parking position determination server **215** may determine that the autonomous vehicle should park off-center and closer to the adjacent vehicle that has the lower risk score.

At step **725**, the parking position information is outputted. For example, the parking position determination server **215** may output the parking position information to the vehicle interface system **210** of the autonomous vehicle. Based on receiving the parking position information, the vehicle interface system **210** may direct the autonomous vehicle to park in the parking space in accordance with the determined parking position. In alternative embodiments, the parking position determination server **215** may output the parking position information to a user device **220** associated with a controller of parking autonomous vehicle. Alternatively, the parking position determination server **215** may output the parking position information to a user device **220** associated with driver of a parking, non-autonomous vehicle.

FIG. **8** illustrates an example user interface for controlling an autonomous vehicle in accordance with alternative aspects of the present invention. As shown in FIG. **8**, a user device **220** may display a diagram or a video of a parking facility, e.g., in an application that can be used to select a parking space for an autonomous vehicle. For example, a camera device **205** associated with the parking facility may provide the video to the user device **220**, and the user device **220** may identify open parking spaces in the parking facility based on the video data. A user of the user device **220** may instruct the autonomous vehicle to park in a particular open parking space, e.g., by dragging and dropping an icon or object representing the autonomous vehicle to an area representing the open space. For example, based on the dragging and dropping, the user device **220** provides an instruction to the vehicle interface system **210** of the autonomous vehicle. The autonomous vehicle may then drive to the open parking space, and capture images of the parking space and of the vehicles parked directly adjacent to the parking space, e.g., using the camera devices **205** of the autonomous vehicle. As described herein, the images are provided to the parking position determination server **215**, and the parking position determination server **215** may determine a parking position within the parking space for the autonomous vehicle. The autonomous vehicle may receive the parking position information from the parking position determination server **215**, and park in the parking space in accordance with the parking position information. In alternative embodiments, information identifying a risk score of the parking space may be displayed on the user device **220**, e.g., based on previously determining the risk score using visual and/or non-visual factors, as described herein. Additionally, or alternatively, colors representing the risk score can be visually displayed. In embodiments, the risk score can be presented as a number and/or a letter, e.g., a risk score of A represents a relatively low risk whereas risk scores of B, C, and D represent incrementally higher risk scores.

While aspects of the invention have been described in an environment including autonomous vehicles, in an alternative embodiment, aspects of the present invention may be used to provide optimal parking position information to a driver of a standard (non-autonomous) vehicle. For example, while images can be received by the parking position determination server from cameras of an autonomous vehicle, in an alternative embodiment, the images can be received by other cameras, such as cameras that monitor a parking facility. In embodiments, a service provider, such as a Solution Integrator, could offer to perform the processes described herein. In this case, the service provider can create, maintain, deploy, support, etc., the computer infrastructure that performs the process steps of the invention for one or more customers. These customers may be, for example, any business that uses technology. In return, the service provider can receive payment from the customer(s) under a subscription and/or fee agreement and/or the service provider can receive payment from the sale of advertising content to one or more third parties.

In still additional embodiments, the invention provides a computer-implemented method for determining an optimal parking position, via a network. In this case, a computer infrastructure, such as computer system **12** (FIG. **1**), can be provided and one or more systems for performing the processes of the invention can be obtained (e.g., created, purchased, used, modified, etc.) and deployed to the computer infrastructure. To this extent, the deployment of a system can comprise one or more of: (1) installing program code on a computing device, such as computer system **12** (as shown in FIG. **1**), from a computer-readable medium; (2) adding one or more computing devices to the computer infrastructure; and (3) incorporating and/or modifying one or more existing systems of the computer infrastructure to enable the computer infrastructure to perform the processes of the invention.

The descriptions of the various embodiments of the present invention have been presented for purposes of illustration, but are not intended to be exhaustive or limited to the embodiments disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art without departing from the scope and spirit of the described embodiments. The terminology used herein was chosen to best explain the principles of the embodiments, the practical application or technical improvement over technologies found in the marketplace, or to enable others of ordinary skill in the art to understand the embodiments disclosed herein.

What is claimed is:

1. A computer-implemented method comprising:

receiving, by a computing device, images of a plurality of adjacent vehicles parked directly adjacent to an open parking space;

determining, by the computing device, visual factors and non-visual factors of the plurality of adjacent vehicles based on the images by obtaining data from a dedicated database;

determining, by the computing device, a parking position within the open parking space based on the visual and non-visual factors; and

outputting, by the computing device, information regarding the parking position.

2. The method of claim **1**, wherein the images are received from one or more camera devices implemented in an autonomous vehicle.

3. The method of claim **1**, wherein the parking position is closer to one of the plurality of adjacent vehicles having visual factors and non-visual factors indicating a lower risk than another one of the plurality of adjacent vehicles.

4. The method of claim **1**, wherein the determining the non-visual factors is based on vehicle identification information included in the images.

5. The method of claim **1**, wherein the images are received from one or more camera devices associated with a parking facility.

6. The method of claim **1**, wherein the visual factors include one or more of:

overall vehicle size;

door size;

door type;

condition; and

distance to another adjacent parked vehicle.

7. The method of claim **1**, wherein the non-visual factors include one or more of:

vehicle history information,

accident history information,

and

published vehicle data.

8. The method of claim **1**, wherein at least one of the visual and the non-visual factors are weighted.

9. The method of claim **1**, further comprising:

determining a risk score for the open parking space based on the visual and non-visual factors of each adjacent vehicle of the plurality of adjacent vehicles; and

outputting the risk score for the open parking space.

10. The method of claim **1**, wherein a service provider at least one of creates, maintains, deploys and supports the computing device.

11. The method of claim **1**, wherein the receiving the images the determining the visual factors and the non-visual factors, the determining the parking position, and the outputting the information regarding the parking position are provided by a service provider on a subscription, advertising, and/or fee basis.

12. The method of claim **1**, wherein the computing device includes software provided as a service in a cloud environment.

13. The method of claim **1**, further comprising deploying a system for selecting a parking space and providing navigation direction to the selected parking space, comprising providing a computer infrastructure operable to perform the receiving the images the determining the visual factors and the non-visual factors, the determining the parking position, and the outputting the information regarding the parking position.

14. A computer program product for determining a parking position for a vehicle, the computer program product comprising a computer readable storage medium having program instructions embodied therewith, the program instructions being executable by a computing device to cause the computing device to:

receive images of a plurality of adjacent vehicles parked directly adjacent to an open parking space when a user of an autonomous vehicle instructs the autonomous vehicle to park in the open parking space;

determine visual factors and non-visual factors of the plurality of adjacent vehicles based on the images;

determine a parking position within the parking space based on the visual factors and non-visual factors; and

output information regarding the parking position to the user of the autonomous vehicle or to a vehicle interface system of the autonomous vehicle to cause the autonomous vehicle to park in the open space in accordance with the determined parking position.

15. The computer program product of claim **14**, wherein the parking position is closer to one of the plurality of adjacent vehicles having visual factors and non-visual factors indicating a lower risk than another one of the plurality of adjacent vehicles.

16. The computer program product of claim **14**, wherein the program instructions to determine the non-visual factors cause the computing device to determine the non-visual factors based on vehicle identification information included in the images.

17. The computer program product of claim **14**, wherein the visual factors include one or more of:

overall vehicle size;

vehicle door size;

vehicle door type;

vehicle condition;

driver experience information; and

distance to another adjacent parked vehicle.

18. The computer program product of claim **14**, wherein the non-visual factors include one or more of:

vehicle history information;

accident history information;

and

published vehicle data.

19. A system comprising:

a CPU, a computer readable memory and a computer readable storage medium associated with a computing device;

program instructions to receive images of adjacent vehicles parked directly adjacent to an open parking space;

program instructions to determine visual factors and non-visual factors of the adjacent vehicles based on the images;

program instructions to determine a risk score for the open parking space based on the visual factors and non-visual factors of each adjacent vehicle; and

program instructions to output the risk score for the open parking space,

wherein the program instructions are stored on the computer readable storage medium for execution by the CPU via the computer readable memory.

20. The system of claim **19**, further comprising program instructions to determine a parking position within the parking space based on the visual factors and non-visual factors; and

program instructions to output information regarding the parking position.

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